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THE RESPIRATORY FUNCTION OF THE HUMAN LARYNX.*

FROM EXPERIMENTAL STUDIES IN THE PHYSIOLOGICAL LABORATORY OF HARVARD UNIVERSITY.

By FRANKLIN H. HOOPER, M. D.,

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The human larynx has two principal functions: (*a*) The respiratory, (*b*) the phonatory. They are mentioned in the order of their importance, for, while the muscles concerned in phonation, supplemented by other constrictors, are charged with the additional duty of closing the laryngeal aperture to protect the air-passages from the entrance of foreign bodies, yet it must be conceded that, whether employed in phonation — marvelous as this function is—or brought into action to exclude some foreign substance, the part performed by these constrictors is entirely subordinate to that of the respiratory muscle of the larynx, whose office is to hold the glottis open in order to insure an uninterrupted passage of air to and from the lungs.† Nevertheless,

* Read before the American Laryngological Association, June 24, 1885.

† The intrinsic laryngeal muscles are in pairs except one, the transverse arytenoid. The posterior crico-arytenoids are the respiratory muscles. The phonatory muscles, which, like the respiratory muscles, are attached to the arytenoid cartilages, are the internal thyro-arytenoids, the lateral crico-arytenoids, and the transverse arytenoid. These

it is this important muscle which is not only the chief among the intrinsic muscles of the larynx, but also one of the most essential of the whole body—a muscle, be it remembered, of *organic life**—that many writers would have us believe has a special tendency to succumb to disease. Gerhardt, in his well-known paper,† was perhaps the first to speak of unilateral paralysis of this muscle (the posterior crico-arytenoid) as the most innocent of all forms of laryngeal paralyses. He points out that neither the voice nor the respiration is impaired in such lesions. Schech‡ writes in the same strain, and believes that, as the voice and quiet respiration are not affected in these instances, this circumstance accounts for their having escaped more frequent mention. Two prominent exponents of this theory (Rosenbach # and Semon ‖) have stated that in central or peripheral affec-

phonatory muscles are, when it is necessary, brought into action solely to close the glottis and not for the purpose of phonation. Under these circumstances they are supplemented by the muscles which compose the aryteno-epiglottidean folds, and which, together with certain other muscular fasciculi, may be classed as the sphincter group—the constrictor vestibuli laryngis. The thyro-cricoids are also phonatory muscles; but with these, on account of their anatomical situation, we have nothing to do in this paper.

* By this expression we refer to the normal automatic character of the muscular action, and not to the microscopic structure of the muscle itself.

† "Studien u. Beobachtungen über Kehlkopflähmung," Virchow's "Archiv," vol. xxvii, p. 88, 1863.

‡ "Experimentelle Untersuchungen über die Funktionen der Nerven und Muskeln des Kehlkopfes," "Zeitsch. f. Biologie," Band ix, p. 258, 1873.

"Bresl. ärztl. Zeitschr.," Nos. 2–3, 1880; "Berlin. klin. Wochenschr.," No. 17, 1884; Virchow's "Archiv," Band 99, 1885.

‖ Mackenzie, "Diseases of the Throat and Nose," German edition, 1880; "Arch. of Laryngology," vol. ii, No. 3, 1881; "Berlin. klin. Wochenschr.," Nos. 46–49, 1883; *Ibid.*, No. 22, 1884.

tions where the filaments of the recurrent laryngeal nerve are compressed, the fibers innervating the respiratory muscle are earlier affected than those going to the phonatory muscles; that this is in accordance with the well-ascertained fact that, in central or peripheral nerve lesions, the extensor muscles * are more readily paralyzed than the flexors; that there is a "proclivity of the *ab*ductor fibers of the recurrent laryngeal nerve to become affected sooner than the *ad*ductor fibers, or even exclusively, in cases of undoubted central or peripheral injury, or disease of the roots or trunks of the pneumogastric, spinal accessory, or recurrent nerves." Another author † has recently gone so far as to say that the vulnerability of these *ab*ductor fibers is a fact upon which all observers are now agreed.

We hazard the opinion, notwithstanding, that if we investigate this complicated subject from a somewhat different point of view—one not strictly clinical—we may discover certain reasons why one should not subscribe unconditionally to this conception of the pathology of laryngeal neuroses. We propose, therefore, to inquire into the truth of this problem purely from an anatomical, physiological, and experimental standpoint. This being, then, in no sense, a clinical paper, clinical evidence will not be offered, although the writer's experience is far from being in accord with the dictum that the nerve filaments which preside over the most useful and important function of the larynx should be especially prone to have that function arrested. The superior laryngeal nerve, and the median laryngeal, recently described by Exner,‡ need not in this study concern us. The only other nerve, as far as we know to-day, going to

* To this assumption that the posterior crico-arytenoid muscles are *extensors* we shall recur.

† Gottstein, "Die Krankheiten des Kehlkopfes," p. 192, Wien, 1884.

‡ "Die Innervation des Kehlkopfes," "Sitzungsb. d. k. Akademie d. Wissenschaften," Band 89, Abth. iii, 1 u. 2 Heft, 1884.

the intrinsic muscles of the larynx is the inferior or recurrent laryngeal. This nerve, according to our present knowledge, is purely motor, * and supplies all the intrinsic laryngeal muscles except the longitudinal tensors, the thyrocricoids. It is an anatomical fact that it does not send off any branches to these muscles until it has reached the border of the cricoid cartilage. In its trunk, therefore, are contained two sets of nerve fibers—the respiratory and the phonatory—which must necessarily be strictly differentiated, since they are destined for muscles which carry on two separate and distinct functions. Now, where do these two sets of nerve filaments come from; is their origin as distinct as their function; whence do they derive their separate individualities; which are relatively or numerically the stronger?

The sources from which nervous impulses for the larynx may be received are the brain, the medulla oblongata, and the spinal cord. The channels through which they may be transmitted are the several motor nerves which join the pneumogastric before the recurrent is given off, for we are aware that from this point the recurrent proceeds to the larynx without any branch or junction which is in any way connected with the functions of that organ.

The experimental researches of Krause,† and the clinical observations of Delavan,‡ justify the belief that there is a

* We are aware that some have stated, but without giving experimental data to substantiate the assertion, that the recurrent contains sensory as well as motor fibers. We have not the space here to dwell upon our own experiments to determine this point, but they justify our remark that the recurrent is "purely motor."

† "Ueber die Beziehungen der Grosshirnrinde zu Kehlkopf und Rachen," "Sitzungsberichte der kgl. preuss. Akad. der Wissensch. zu Berlin," November, 1883.

‡ "On the Localization of the Cortical Motor Center of the Larynx," New York "Med. Record," February 14, 1885.

center of motion for the larynx in the cortical substance of the brain. It is also probable, as advanced by many, that the several nerve filaments of the recurrent laryngeal may have independent ganglionic centers somewhere in the brain or medulla. Let us now follow down the real motor nerve tract of the larynx from the medulla oblongata to the point of exit of the recurrent laryngeal from the pneumogastric, and enumerate the different nerves which, from what we know positively or imagine hypothetically, may in any way influence either of the functions of the larynx. In so doing we shall adopt Longet's classification,* who divided them into the *direct* and the *indirect*. Starting, then, at the medulla, we name as the direct communications to the pneumogastric the internal branch of the spinal accessory, the facial, the hypoglossal, and the anterior branches of the first and second cervical. The sympathetic may also furnish some direct fibers. Under the head of indirect nerves—namely, those which join the pneumogastric after having previously passed through the sympathetic ganglia—we have all the branches of the cervical below the second, and those of the dorsal nerves situated, of course, above the point where the inferior laryngeal shoots off from the pneumogastric to run its backward course to the laryngeal muscles.

Our knowledge of the part played by these different nerves in the performance of the functions of the larynx is now, and, from the inherent difficulties of the problem, must for a long time to come remain, unsatisfactory. The mass of contradictory statements which one encounters in working up a subject in any way connected with the respiration, and consequently with the pneumogastric nerve, is a sufficient admonition against too positive and dogmatic assertions. We approach this question, therefore, with reserve, admitting, as we must, that a great part of

* "Traité de physiologie," vol. iii, p. 512, Paris, 1869.

the subject is yet hardly beyond the confines of plausible conjecture.

It is pretty certain, however, as determined by the reliable experiments of Bischoff,* Longet,† Cl. Bernard,‡ and Schech (*loc. cit.*), that the spinal accessory is a purely motor nerve presiding over phonation, and having nothing to do with the respiratory function of the larynx.# That there may be other phonatory fibers in the pneumogastric we can not gainsay. Now, how is the respiratory function innervated? Probably in many different and complex ways, in accordance with the truth of the physiological law enunciated

* "Nervii accessorii Willisii anat. et physiol.," Heidelberg, 1832.

† "Rech. expérimen. sur les fonctions des mus. et des nerfs du larynx," etc., "Gaz. méd. de Paris," 1841.

‡ "Fonctions du nerf spinal," etc., "Leçons sur la physiologie et la pathologie du système nerveux," tome ii, Paris, 1858.

Experimental physiology teaches us that if we cut the recurrent nerves of a kitten or a puppy a few days old it immediately dies of suffocation, which is not the case in old animals. The reason of this, as originally explained by Legallois ("Expériences sur le principe de la vie," Paris, 1812), is because in very young animals the cartilaginous portion of the glottis is but slightly developed, and, the soft and yielding parts not being held in position by the muscles, the laryngeal walls are sucked together by the inspiratory effort, and the laryngeal aperture is accordingly completely closed. Cl. Bernard showed that section of the spinal accessory in a kitten five weeks old was followed by aphonia, but glottic respiration remained free. Two days afterward, the kitten having remained well but voiceless, its recurrents were cut, when it instantly died asphyxiated. He concludes from this that the pneumogastric has a motor power independent of the spinal accessory which permits the animal to breathe after the latter has been cut; or, in other words, the larynx is a vocal organ when excited by the spinal accessory, and a respiratory organ when under the influence of the pneumogastric, or more probably of other motor nerves associated with it. In certain animals, as the chimpanzee, the internal branch of the spinal accessory does not blend with the pneumogastric, but goes direct as a separate nerve to the larynx.

by Longet.* "Les moyens d'innervation propres à entretenir le jeu d'un organe se multiplient en raison de son importance physiologique." The posterior crico-arytenoids—the respiratory muscles of the larynx—are paramount to all the rest in physiological importance. From many sources they receive an abundant nerve supply, which is to protect them from disease, not to open up new channels by which harm might come to them. With others we assume that there are independent ganglia in the central nervous system which are essentially their own. Being respiratory muscles, it is more than probable that they may receive nerve force from such respiratory nerves as the facial, the hypoglossal, and the others already mentioned which run into the pneumogastric. But in this connection we must quote Longet's own words:† "Si la phonation, fonction secondaire et accessoire, dépend d'un nerf unique et disparaît avec lui, la dilatation respiratoire de la glotte, si essentielle, si indispensable à la conservation de la vie, est sous la dépendance ou plutôt sous la protection de nerfs multiples qui, dans certains limites, peuvent se suppléer les uns les autres. Aussi, comme je l'ai déjà fait remarquer, précisément avant de donner origine aux récurrents qui animent les muscles crico-aryténoïdiens postérieurs, voit-on les pneumogastriques emprunter des fibres motrices à des nerfs qui tous interviennent dans la respiration."

Summing up what has preceded, we can say that it all points to the conclusion that the respiratory nerve filaments contained in the recurrent laryngeal are derived from a greater variety of sources than the phonatory.

We pass now to the experimental evidence bearing on this point. It is a fact, familiar to all, that if anything

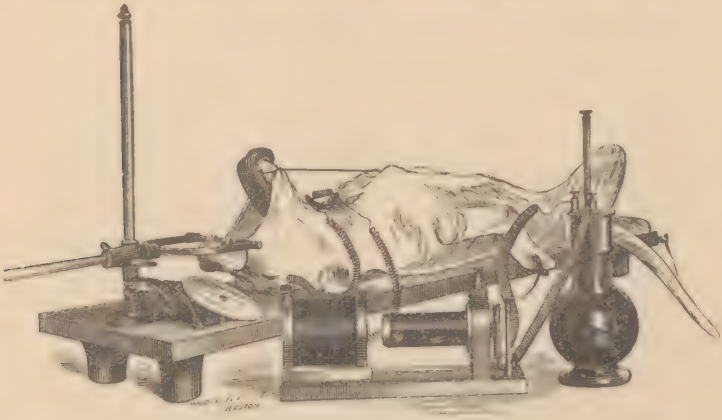
* "Traité de phys.," vol. iii, p. 517, Paris, 1869.

† *Loc. cit.*, p. 518.

other than air finds its way into the larynx it produces, by reflex action, a sudden closure of the glottis. It is equally certain that, under normal conditions, the same contraction of the laryngeal muscles may be instantly called forth by direct stimulation of one or both of the recurrent nerves. Now, it may with reason be asked, How is it that this constricting action of the phonatory muscles is brought about if it be true that the nerve fibers animating the dilators of the glottis are the stronger and the more numerous? Why should we not get *ab*duction of the vocal bands instead of *ad*duction on irritating the recurrent nerves? The phonatory muscles are to the respiratory muscles as five to two, and the closure of the glottis has always been ascribed to the superior numerical strength of these constrictors. Yet if we compare, bulk for bulk, the muscular fibers which compose the five muscles of phonation with those of the two respiratory muscles, we do not find that they are much, if any, in excess of the latter, and we venture to think that there is some other factor concerned in this phenomenon apart from mere muscular force. It may be sought, perhaps, in this important difference between the respiratory and the phonatory function of the glottis—namely, that, while the respiratory muscles are ever on the alert, holding the glottis open during the entire healthy life of an individual, in his waking as well as in his sleeping hours, the phonatory muscles, on the other hand, are more dependent upon the *consciousness* of the individual in order to respond to any irritation. To explain: The phonatory function of the phonatory muscles could, as far as life is concerned, be dispensed with. Not so their constricting action with the view of excluding the passage of foreign bodies to the lungs. The constrictor muscles of the larynx are the sentinels who guard the approach to these vital organs. But they cease to act if the animal is in profound narcosis; they are asleep,

so to speak, on their watch. A man in the condition known as "dead drunk," lying, let us suppose, on his back with his mouth open, would offer no obstacle to prevent any living insect that chanced his way from crawling in and out of his mouth, or meandering round in his larynx *à volonte*, without exciting reflex contraction of its muscles. The power of ether, chloroform, and other anæsthetics to impair the action of these constrictors is too well known to need mention. To carry this line of thought a little further, should we not expect that, provided we could preserve the organic life of an animal while its volition was at the same time completely abolished—should we not expect, we ask, under these circumstances, to get a dilatation of the glottis on irritating the recurrent nerves instead of a closure, for the posterior crico-arytenoid muscles are muscles of organic life? Indeed we believe we should, and we submit the following experiments in support of that belief. In performing the experiments the writer has had the advantage of the collaboration of Professor Henry P. Bowditch, to whom he would express his thanks. With one exception, when a horse was the subject of an experiment, the animals used were dogs, the proper selection of which for studies in experimental laryngology is highly important. If a dog is either very old or very large he is most unsatisfactory, if not absolutely worthless. He should be small and young; the breed is of no consequence. By arranging him in the following manner a perfect view of the glottis can be obtained: After being thoroughly etherized, he is secured on his back to a dog-holder. A longitudinal incision is made in the skin covering the larynx, the fascia is divided, and the muscles are drawn aside. The larynx and trachea are thereby brought into view. One or both of the recurrent laryngeal nerves may now be exposed. The mouth is held open by the upper jaw being firmly attached to the cross-bar of the dog-

holder, while a cord, tied round the lower jaw and secured to any fixed point, keeps the jaws separated to the extent desired. If the animal is placed before a window, the light is transmitted through the wall of the trachea, illuminating the glottis below, while the ordinary head reflector throws the light in through the open mouth from above. The tongue may be stretched up over the lower jaw and secured to the skin by a thread. The epiglottis may be either tied up by a string passed through its tip, or held up by an instrument suitably curved, having a long handle. The accompanying picture, taken from a photograph of a dog in



readiness for experimentation, may serve to make our description somewhat clearer. The animal is here shown under conditions by which both recurrents could be stimulated simultaneously.*

* For the sake of completeness of the figure, the primary coil is represented as connected with a small bichromate cell, but in practice it was connected with a Grove cell in a battery-closet. The induction apparatus is the one described and figured in the "Proceedings of the American Academy of Arts and Sciences," October 12, 1875.

The phenomenon of an irritation applied to the recurrent laryngeal nerve producing an *ab*duction of the corresponding vocal band was first observed by accident. A small dog, of no particular breed, of an age estimated at about ten months, as it still had some of its puppy teeth, was being prepared for a different order of research. On looking for the left recurrent nerve, it was not found in its proper anatomical situation, but two small nerves were discovered near by. As it was doubtful what these two branches were, or whether they went to the larynx at all, a shielded electrode was placed on the outer and larger nerve, and, while the vocal bands were watched through the mouth, it was irritated. The very unexpected result of the stimulation was a forcible *ab*duction of the left vocal band. Dr. J. W. Warren, assistant in physiology, was requested to come and witness this unusual sight. The ether sponge had been removed from the dog since the beginning of the experiment, and by the time Dr. Warren was ready to look at the larynx the animal was somewhat out of its influence.* At all events, on stimulating the nerve a second time, the familiar closure of the glottis was manifested instead of the dilatation so evident a few moments before. On the assumption that the degree to which the animal was narcotized might have something to do with these phenomena, a large quantity of ether was again administered. After the dog was profoundly under its influence, the nerve was irritated a second time, when both Professor Bowditch and Dr. Warren observed the *ab*duction of the vocal band, which was more marked in proportion as the stimulation was more intense. On removing the anæsthetic the dilatation became less and less as the animal regained its consciousness, when finally a contraction of the glottis supervened. The different stages in this experiment were readily followed by

* Not in any of these experiments sufficiently to feel pain.

watching the dog's vocal bands while, at the same time, the recurrent nerve was irritated at intervals of a few moments. Between extreme dilatation and forcible contraction, under these circumstances, there seemed to be a neutral point, so to speak, when the stimulation produced merely a vibratory movement of the vocal band; but this was soon succeeded by an attempt at contraction, and this in turn passed into a frank and decided closure of the glottis as the animal, as before mentioned, came out of the effects of the ether. Similar results followed stimulation of one or the other of the divisions of the left recurrent nerve. These branches, as was shown by subsequent dissection, and as you will see on the specimen, united into one nerve fifteen millimetres below the cricoid cartilage, and from this point to the larynx it is a single nerve. The effects of irritation applied to the right recurrent (which was single) agreed with those on the left. Stimulation was effected by means of an ordinary induction apparatus,* the intensity varying from 1 to 40. In general, however, in this and in subsequent investigations on other dogs, the intensity used was from 1 to 8, never over 10, and generally about 3. The experiment many times observed on this animal was repeated, with confirmatory results, on eight different dogs. But the extent and the force, it must be mentioned, with which the vocal bands were *ab*ducted differed in different dogs. In five instances the arytenoid cartilage was rotated outward so forcibly that the vocal band lay flat against the wall of the larynx. Moreover, in one case there was a marked *ab*duction of the vocal band on the opposite side. In

* The electrical apparatus was the same as that used by the writer in former experiments, to which the reader is referred for an explanation of the terms employed. (See "Experimental Researches on the Tension of the Vocal Bands," "Trans. of the Amer. Laryngological Association," 1883, p. 121.)

other dogs a *mixed* movement was observed—that is, the band approached the median line anteriorly, while a simultaneous contraction of the posterior crico-arytenoid muscle took place posteriorly, which left, in the respiratory portion of the glottis, a large triangular opening, the glottic picture resembling an exaggerated form of paralysis of the arytænoidæus transversus muscle. These phenomena were observed after the recurrent nerve had been cut and its peripheral end stimulated as well as when the nerve was intact. Usually when a young dog is under ether the vocal bands are seen moving rhythmically and regularly with respiration. Occasionally, in this condition of profound narcosis, we noticed that, although the animal was breathing, the respiratory excursions of the vocal bands had entirely ceased, the glottis remaining widely dilated. As soon as the respiratory movements had recommenced, irritation of the recurrent nerve was followed by the usual *ab*duction of the vocal band, an action we have become accustomed to regard as the normal one, *provided* the consciousness of an animal is completely abolished by sulphuric ether. The most striking demonstration, however, of this dilatation of the glottis is obtained by placing an electrode on each of the recurrent nerves and irritating the two nerves at the same time. Both arytenoid cartilages are now rotated simultaneously outward, the glottis is held widely open during the stimulation, and the effect is one not soon to be forgotten. Krause* has noticed the difference in the mobility of the vocal bands according as the animal was more or less narcotized. Just in proportion as consciousness was deadened, the *ad*ductors became sluggish. We have repeatedly observed the same effect when the dog was under morphine, chloral, or chloroform, but we failed

* "Experimentelle Untersuchungen und Studien über Contracturen der Stimmbandmuskeln," Virchow's "Archiv," Band 98, 1884.

with all these agents to obtain the total abolition of the action of the constrictors, on irritating the recurrent nerves, which is so marked when large quantities of ether, which can be given with safety, are administered.

From the enormous development of the respiratory laryngeal muscles of the horse we conjectured that their contraction might be even more easily called forth than that of a dog's. In this we were disappointed in the single experiment we have performed on this animal. Chloroform was the anæsthetic used. An incision was made in the hyro-cricoid membrane, through which the finger was inserted and directed between the vocal bands. On irritating the recurrent nerve the finger was tightly squeezed by the contracting glottis. It is probable, however, that if ether had been employed instead of chloroform, and the horse thoroughly saturated with it, we should have felt the glottis dilate and not contract. We were indebted to the Harvard Veterinary College for this observation, and chloroform, for reasons of convenience, is the only anæsthetic used in that institution.

With a view to ascertaining whether certain fibers in the recurrent were more vulnerable than others, we undertook a series of observations of which the following may be taken as the type: The nerve was exposed and a small crystal of chromic acid was laid upon it. The electrode being placed below this point, the nerve was irritated at intervals while the chromic acid was working its slow destruction. In order to watch the effect upon the vocal band, the dog was arranged as in the previous experiments. When the animal was thoroughly etherized, the results did not differ materially from those already described. Stimulation produced *ab*duction of the vocal band. As the destructive process of the acid progressed, the vocal band gradually became completely paralyzed. But, even after the respiratory

movements of the vocal band had entirely ceased, irritation was followed by an outward rotation of the arytenoid cartilage. This was only occasionally seen, and lasted but a moment, for, as soon as the conductivity of the nerve was completely destroyed, stimulation naturally produced no effect. We can only say that under these circumstances we were able to produce an *ab*duction of the vocal band as long as *any* action at all was produced. How early or how late in the destructive process the *ad*ductor or phonatory filaments were attacked we know not. Being few in number (probably) as compared with the respiratory filaments, and as ether, as we have shown, arrests so effectually their action, we can not say here whether there was a "proclivity" of either the one set or the other to become affected. We simply demonstrated that the *ab*ductors held on to the last moment, for, as long as a single nerve-fiber of any kind was left intact, we got a contraction of the posterior crico-arytenoid muscle. When the destruction of the nerve was complete, the vocal band stood motionless in the cadaveric position.

In proceeding now to a new order of experiment, we are able to record the endurance of the respiratory filaments contained in the recurrent laryngeal nerve, while those destined to supply the phonatory apparatus were altogether unable to respond to stimulation. We took a small, young dog, exposed the left recurrent nerve, and carefully passed a thread through the middle of it. The two ends of the thread were tied together in order to prevent its slipping out, but no pressure was exerted on the nerve itself. The object of the thread was simply to act as a foreign body. It was hoped that inflammation might thereby be excited, and, as the respiratory or phonatory fibers were the more readily attacked, the effect of an irritation applied to the nerve below the thread would be followed by certain derangements of motion of the vocal band. After the thread had been

secured in the nerve, the parts were restored as nearly as possible to their normal situations, and the incision in the neck was sewed up. Inspection of the glottis showed that both vocal bands were moving normally with respiration. The following day the dog was again etherized and the glottis examined. No apparent change had taken place in either the appearance or natural mobility of the parts. The nerve was not disturbed. Since the thread had been introduced in it the nature of the dog had undergone a change. From having been a confirmed howler he had become a model of propriety. This happy improvement in his disposition lasted until he was destroyed. The quieting effect of a thread in the recurrent nerve has been noticed in many dogs subsequently. At the end of a week, the dog having been etherized and the glottis inspected on four different occasions, he was again placed under the anæsthetic. As soon as a cannula could be placed in the external jugular vein chloral was injected into it and the ether removed. It is important to remember that in the following experiments the animal was chloralized and not under the influence of ether. A slight but evident change was now observable in the vocal band corresponding to the nerve operated upon. Although the arytenoid cartilage of this side appeared to move with respiration as naturally as did the right cartilage, the anterior portion of the left vocal band seemed to have lost its "tone"; it did not come up with the same "snap" on expiration as its fellow. On opening the incision in the neck, the nerve was found imbedded in a considerable mass of inflammatory tissue, from which it was impossible to separate it. After exposing the nerve below this point, it was placed in a shielded electrode. Irritation with an intensity varying from 1 to 10 produced *ab*duction of the left vocal band, and cessation of its respiratory movements, the band remaining in the position of

deep inspiration as long as the stimulation was kept up. On ceasing the irritation the respiratory movements went on as before. The right vocal band was in no way influenced when the left recurrent was stimulated with an intensity not exceeding 10. When, however, a more powerful stimulation (15) was employed, the right vocal band was brought to the median line (phonatory position), while at the same time the left band was pulled outward. We have, then, here a double effect: *ad*duction of the vocal band on the healthy side, and *ab*duction on the side where some alteration had taken place in the nerve fibers; or, in other words, the normal action of constriction of the right side was manifested while the left band was *ab*ducted, owing to the degeneration of the phonatory fibers, the respiratory filaments remaining unharmed; and, consequently, the respiratory muscle alone responded to the stimulation. The right vocal band was now paralyzed by section of the right pneumogastric, the band coming to a standstill in the cadaveric position, or the position we are accustomed to see in cases of "recurrent paralysis." Stimulation applied to the right recurrent resulted in a smart closure of the glottis, effected by the right vocal band being brought forcibly against its fellow, as well as by the contraction of the arytænoidæus transversus, which approximated the two arytenoid cartilages. It could not be accurately determined whether the anterior portion of the left band contracted or not, as even a feeble irritation produced such a rapid and complete closure of the laryngeal aperture. If the closure of the left vocal band was brought into action, it was very slight: it was evident that the closure of the glottis was chiefly effected by the contraction of the constrictors on the right side, and by the arytænoidæus transversus muscle. The electrode was again changed to the left recurrent below the insertion of the thread. Stimulation was followed by

the same outward rotation of the left arytenoid cartilage as was observed in the first experiment. There was also a marked movement of the right arytenoid cartilage toward its fellow, as if by the contraction of the arytænoidæus transversus muscle. The action of this muscle was prominently brought into play in the next experiment, when the peripheral end of the left recurrent was stimulated, after section of the nerve below the thread. Both vocal bands were now paralyzed and standing in the cadaveric position. All avenues to the brain were thereby cut off except through the anastomoses of the terminal branches of the recurrent with those of the superior laryngeal, and, perhaps, also with those from the pharyngeal plexus. Irritation of the peripheral end of the left recurrent produced both a contraction of the left posterior crico-arytenoid and transverse arytenoid muscles. That is, there was a distinct outward rotation of the vocal process of the left arytenoid cartilage, and an approximation of both arytenoid cartilages at the same time.

Positive as were the results of this series of experiments, we lay no stress upon them. If they are of any worth, it will be by suggesting to others some better method than was here employed, for all our attempts to verify the observations have failed. Even when the thread had been previously soaked in a one-per-cent. solution of chromic acid it did not cause any material disturbance when introduced through the nerve and retained there for many days. The only change noticed was that, in some of the dogs, a more powerful stimulation was required to produce a contraction of the vocal muscles through the nerve operated upon than in the opposite healthy side.

CONCLUSIONS.

The principal fact herein demonstrated is, to our mind, the power and the endurance of the posterior crico-arytenoid

muscles and of the nerves which supply them. We have spoken of the theoretical reasons: (1) The physiological importance of these muscles; (2) their belonging to organic life; (3) their extensive nerve-supply, all of which would tend to preserve their functional integrity. Moreover, if it be true that there is a "proclivity" of the *ab*ductor fibers to become diseased, and that unilateral paralysis of the abductor muscle is such a common and harmless lesion, should we not expect, theoretically, that bilateral paralysis of this muscle would occur more frequently? Yet there can be no dispute whatever that bilateral paralysis of the posterior crico-arytenoids is a disease as rare as it is grave.

Now, with regard to these muscles being *extensors*, and, like the extensors in other parts of the body—the forearm, for instance—more liable to succumb to disease than the flexors, we would ask this simple question: Why should the terms "extension" and "flexion" be applied to the rotation of the arytenoid cartilages? The principal office of the posterior crico-arytenoids is to maintain the respiratory patency of the glottis. From the beginning to the end of life they are in a state of semi-contraction—holding the glottis open. They come, therefore, just as near being flexors as extensors; but, as a matter of fact, they are neither the one nor the other in the ordinary acceptation of these terms as applied to muscles of the general system. They are *respiratory* muscles carrying on a special function. One might as well speak of the movements of the pupil as extension and flexion, or compare the diastole of the heart to the extension of the forearm, or its systole to the bending of the little toes. Muscles are analogous as they discharge analogous functions. We recognize no more analogy between the posterior crico-arytenoid muscles of the larynx and the extensor communis digitorum of the forearm than there is between "respiration" and "prehension." If we

wish to seek muscles that are analogous, let us turn to other respiratory muscles and ask how they are affected by disease. In diffused, progressive diseases of the nervo-muscular system we know that of all muscles, except the heart itself, those belonging to the respiratory system are always the last to be attacked, and there is no valid reason why the respiratory muscles of the larynx—either one or both—should offer an exception to the rule, especially as they are the most important of all.

We propose to investigate this subject from a clinical aspect at some future date, when, perhaps, the positions which immobile vocal bands assume may be sufficiently explained without attributing to a wise and conservative nature a "proclivity" to attack one of the most vital muscles of the human system.